Ionisation laser system

Update on coverage calculation - FD SP module

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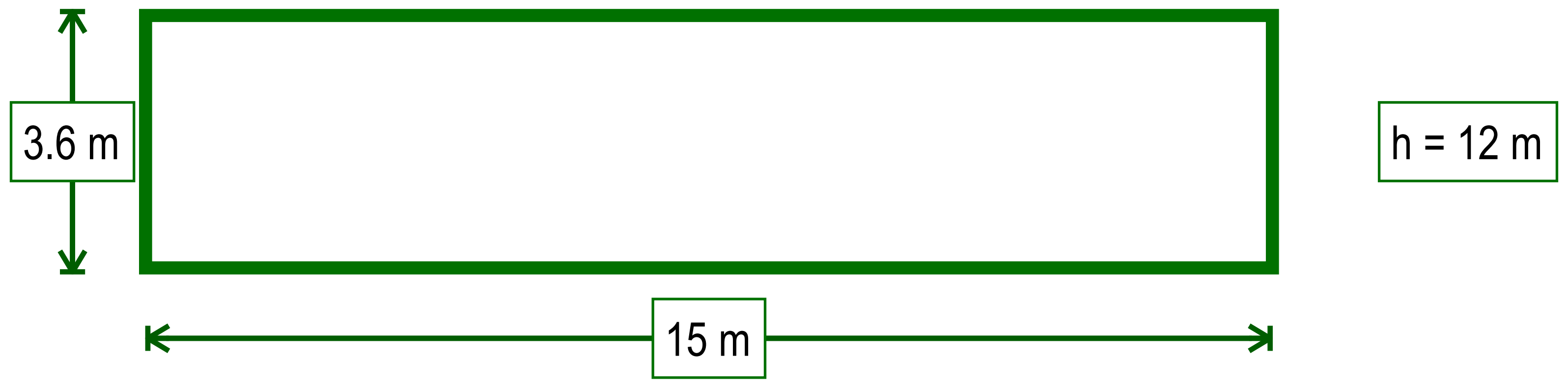
Laser WG meeting - June 18th 2020

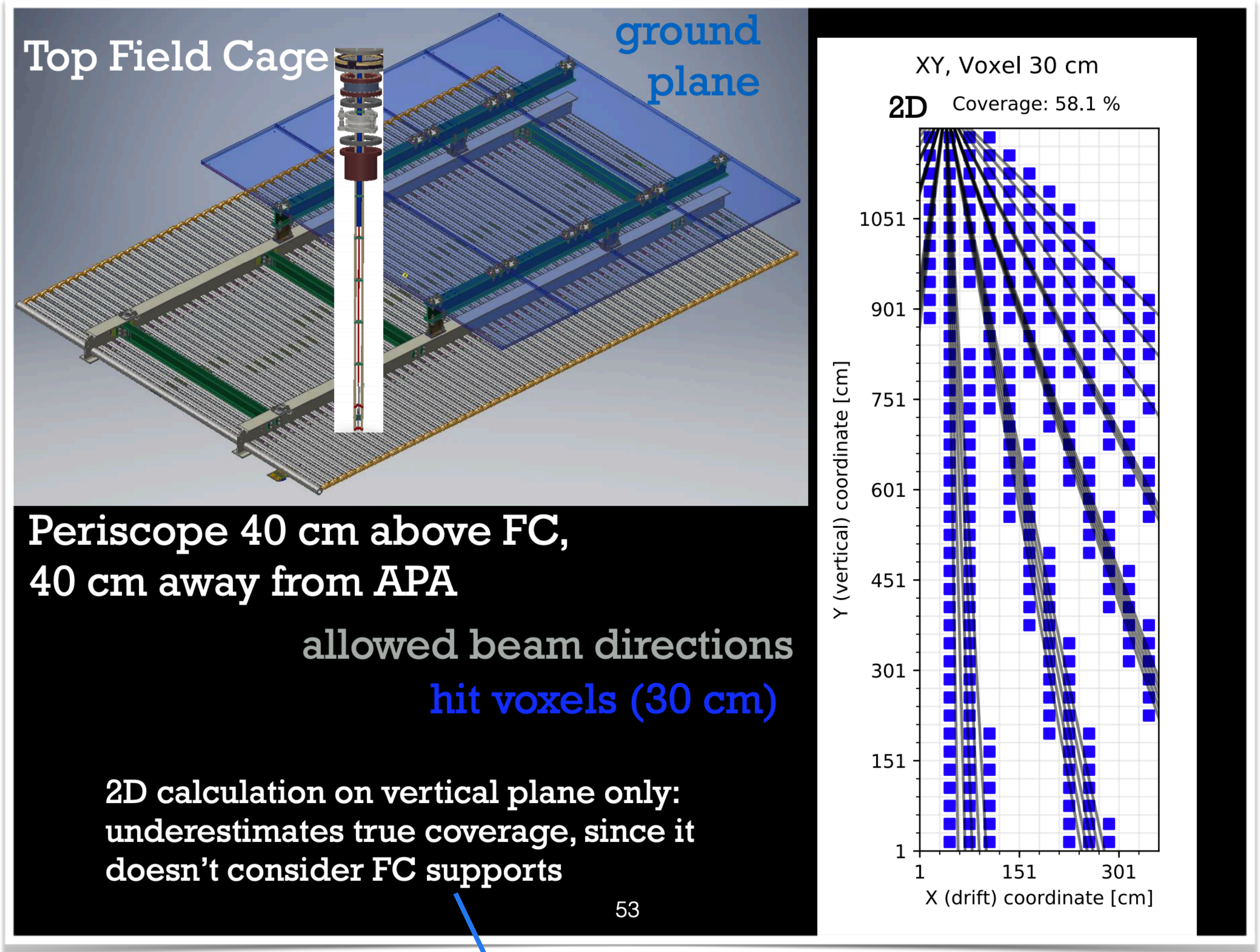
DUNE FD SP module

Top of the cryostat view



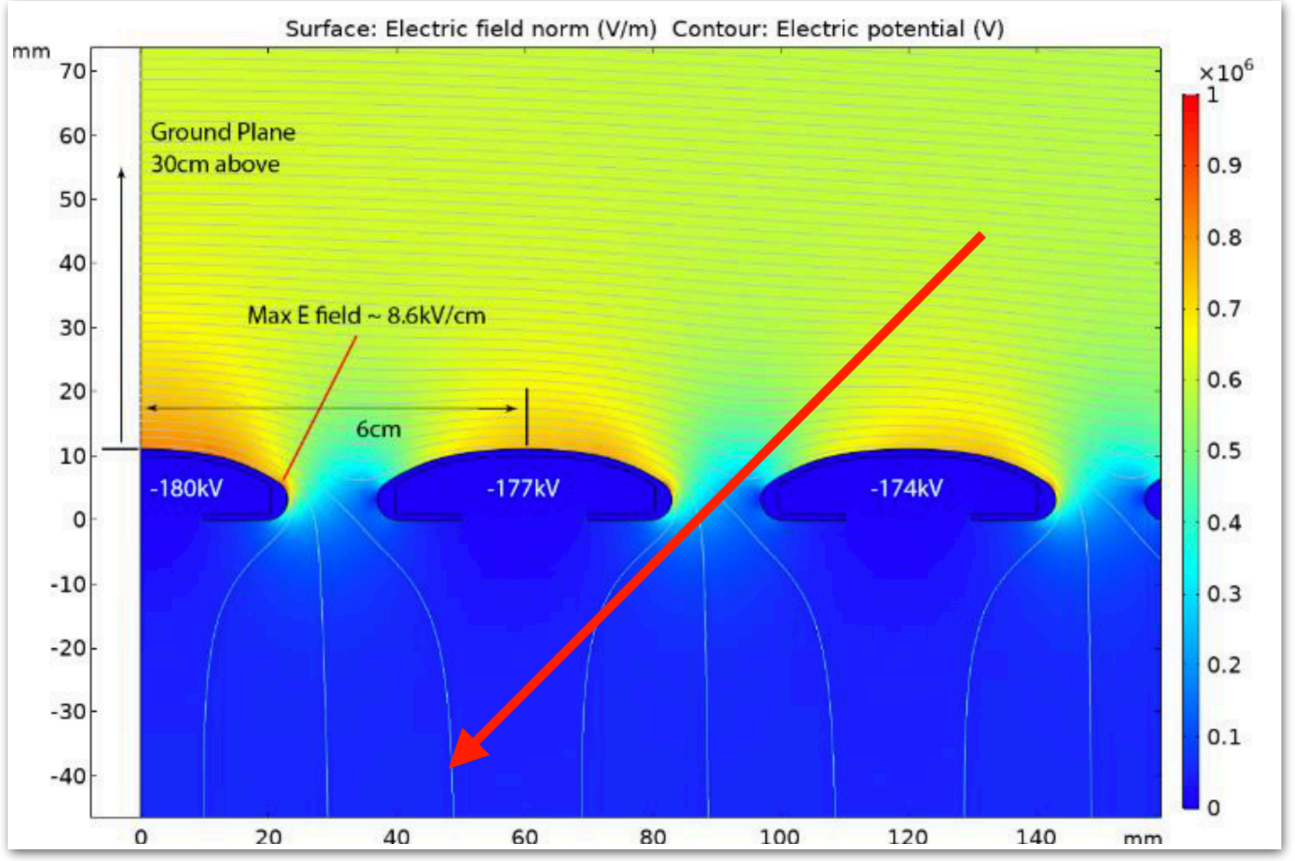
16 sectors, one laser port each

Results of the existing simulation



Need of a 3D calculation

	30 cm	10 cm
APA	58%	31%
no APA	56%	30%



Assumptions:

- Laser rays direct in the gaps between FC profiles
- Maximum angle ~45º
- Number of laser rays decreasing with the angle increase to simulate the FC profile thickness
- 2D simulation
  Only the vertical plane below the laser fire point is considered

[J. Maneira, FD calibration workshop, June 18th, 2019]

Highlights of the new simulation

- Designed as a 3D calculation
- Modular
- Ready for future upgrades
- Easy to extend to different FD sectors
- Written with the idea of future sharing
- User friendly:
  - Large use of absolute quantities
  - Classes are implemented as private entities. The user cannot access reserved parts of the code
- Focus on a single FD sector (3.6 x 12 x 15 m), easily scalable

- Obstacles are all defined in a dedicated class
  ➡ can be separately included in each run
  - ✓ Top FC profiles,
  - ✓ I-beams,
  - ✓ Resistor plates,
  - ✓ End-wall FC profiles,
  - ✓ End-wall supports
- Laser tracks can have variable increment:
  - Safe for voxel scoring inside the detector volume
  - More accurate when close to the obstacles
- Laser directions can be defined both
  - by polar coordinates
  - by coordinates of the destination point

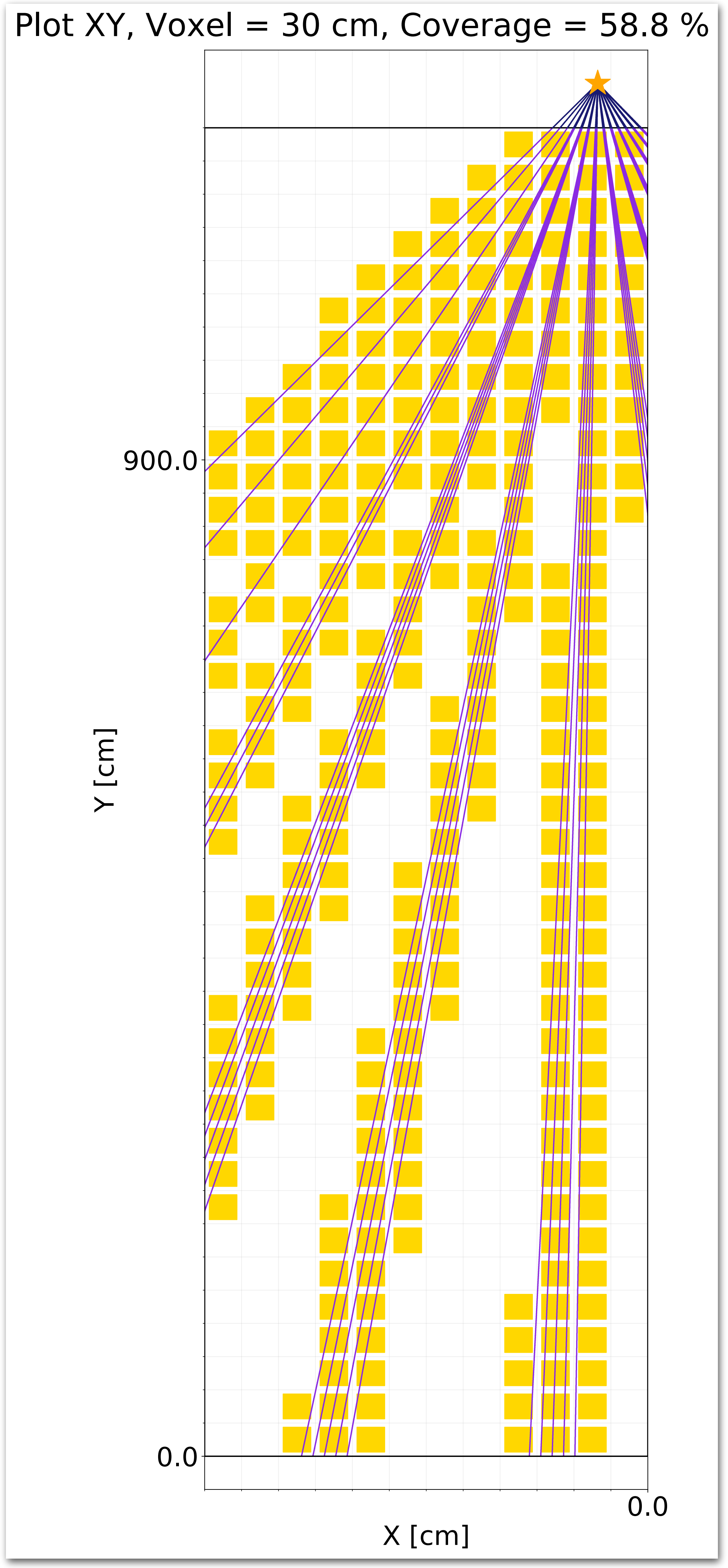
Reproducing 2019 simulation results

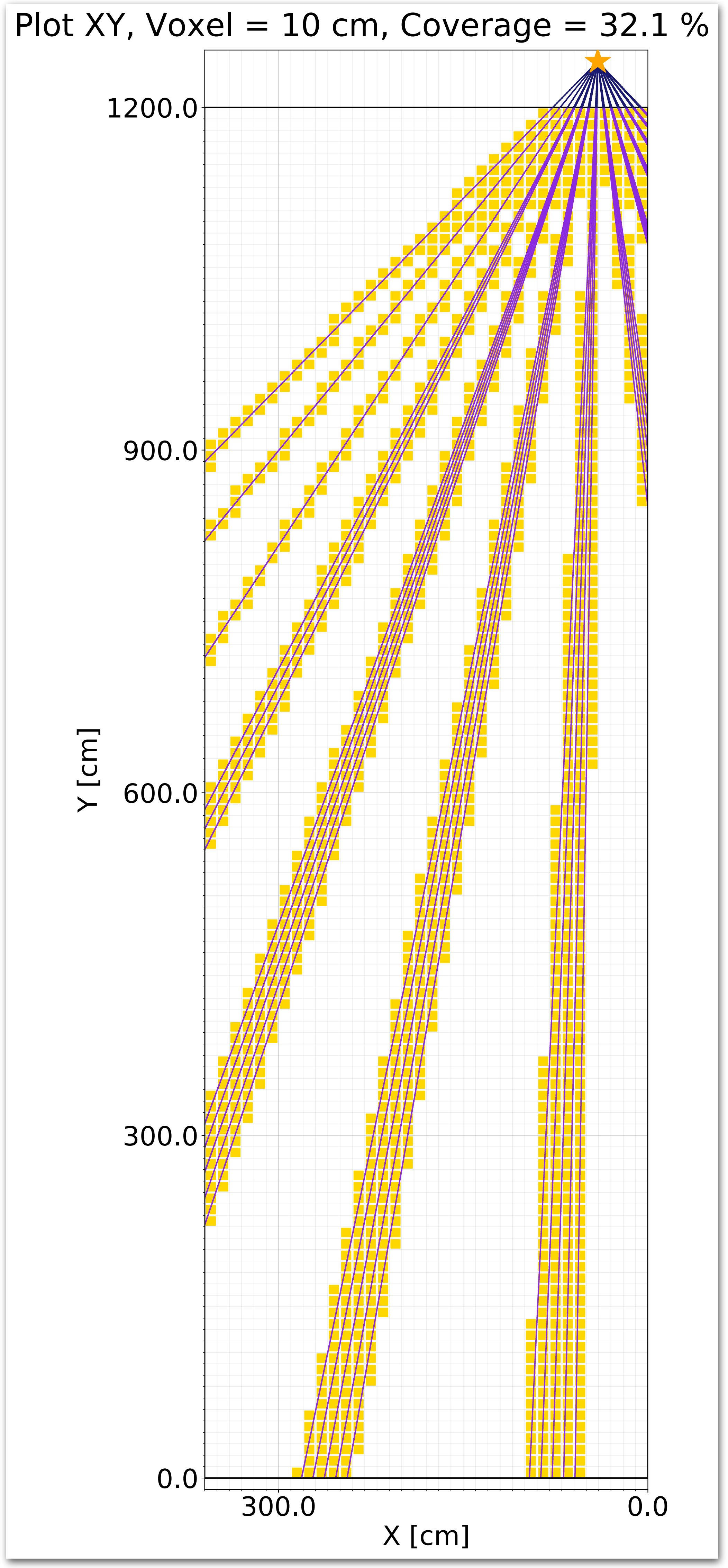
Conditions in the 2019 code:

1. Only the first voxel on the z-axis was considered
2. FC profiles have no thickness. Laser tracks simply do not cross the position of the profiles.
3. A different number of laser rays are generated for each gap between profiles. Profile gaps close to the fire-point have 5 rays.
   Gaps far from the laser fire-point have 1 ray.
   The last considered track is 45º inclined with respect to the laser fire-point projection.

Here, the same conditions are reproduced

1. The detector thickness is reduced to the dimension of one voxel
2. All the FC profiles are removed
3. Laser rays are generated in a similar way.





2019	Vox = 30 cm	Vox = 10 cm
APA	58.1%	31%
no APA	55.8%	29.6%

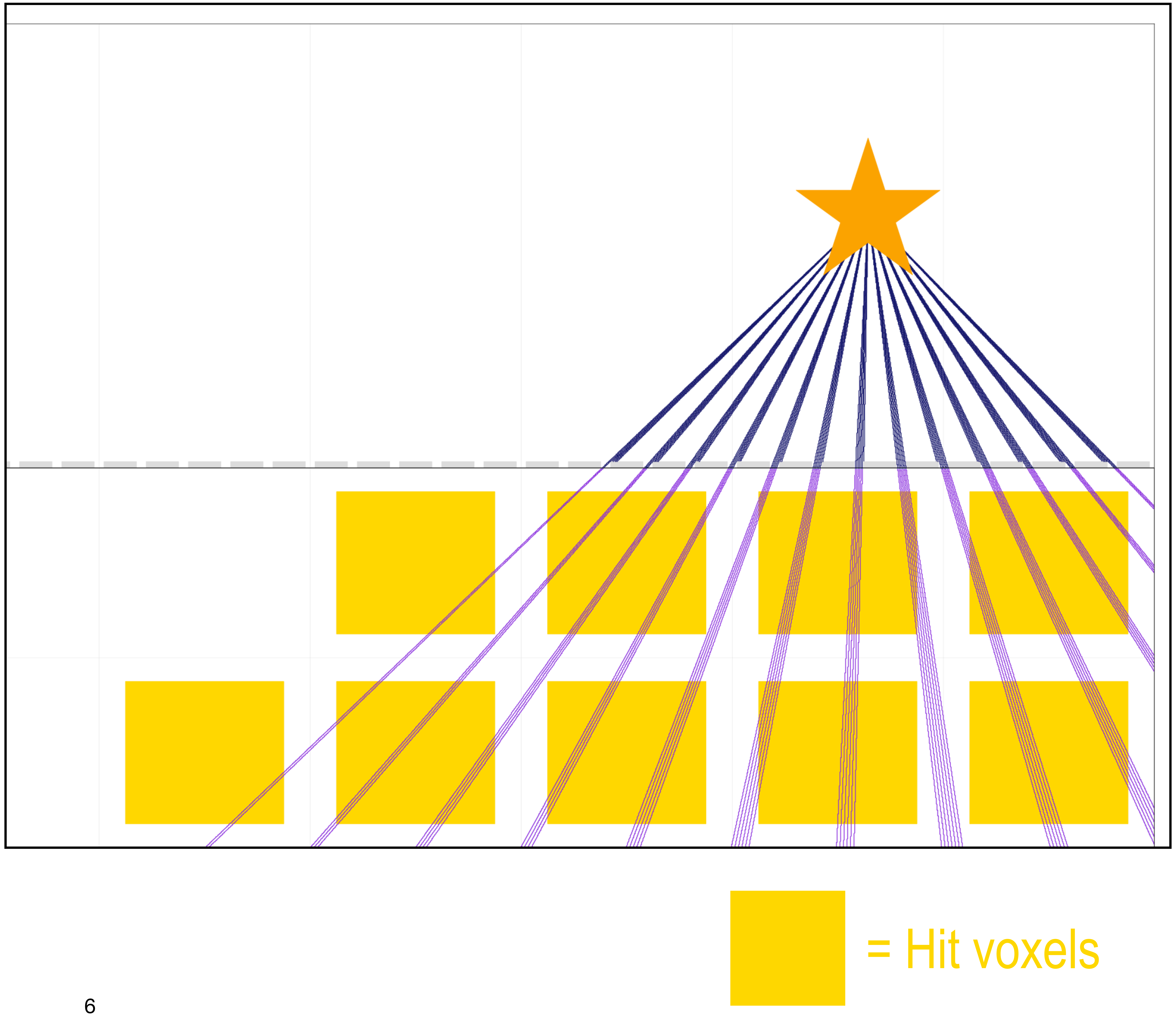
2020	Vox = 30 cm	Vox = 10 cm
APA	58.8%	32.1%
no APA	56.2%	30.4%

Including objects Top FC profiles

- Laser rays are blocked by the obstacles
- Rays are directed at equally distanced points in the gaps between top FC profiles
- Last laser ray is at 45º angle, same as for 2019 calculation
- Here FC profile section is rectangular. A more realistic shape can be designed in a future upgrade
- There is room for a few rays at greater angles than 45º.

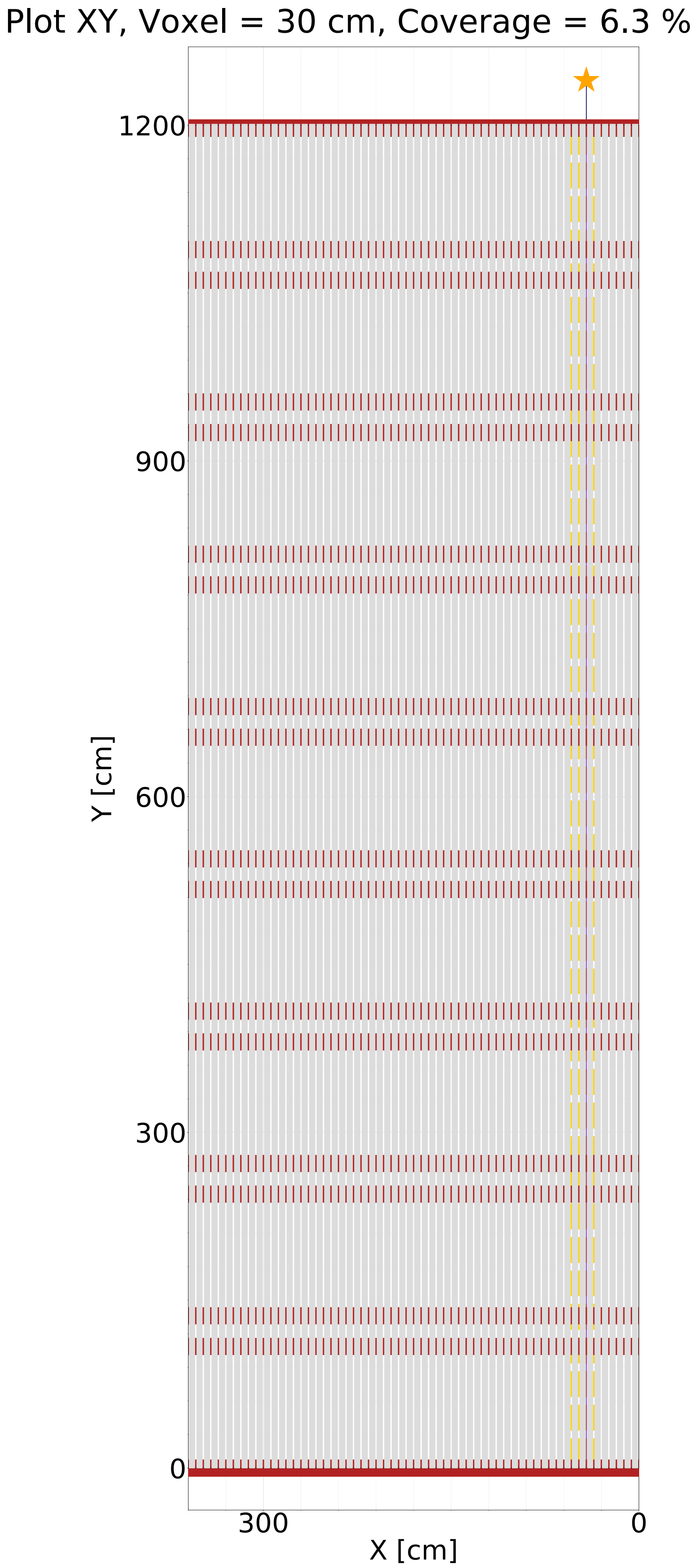
2019-like	Vox = 30 cm	Vox = 10 cm
APA	58.8%	32.1%
no APA	56.2%	30.4%

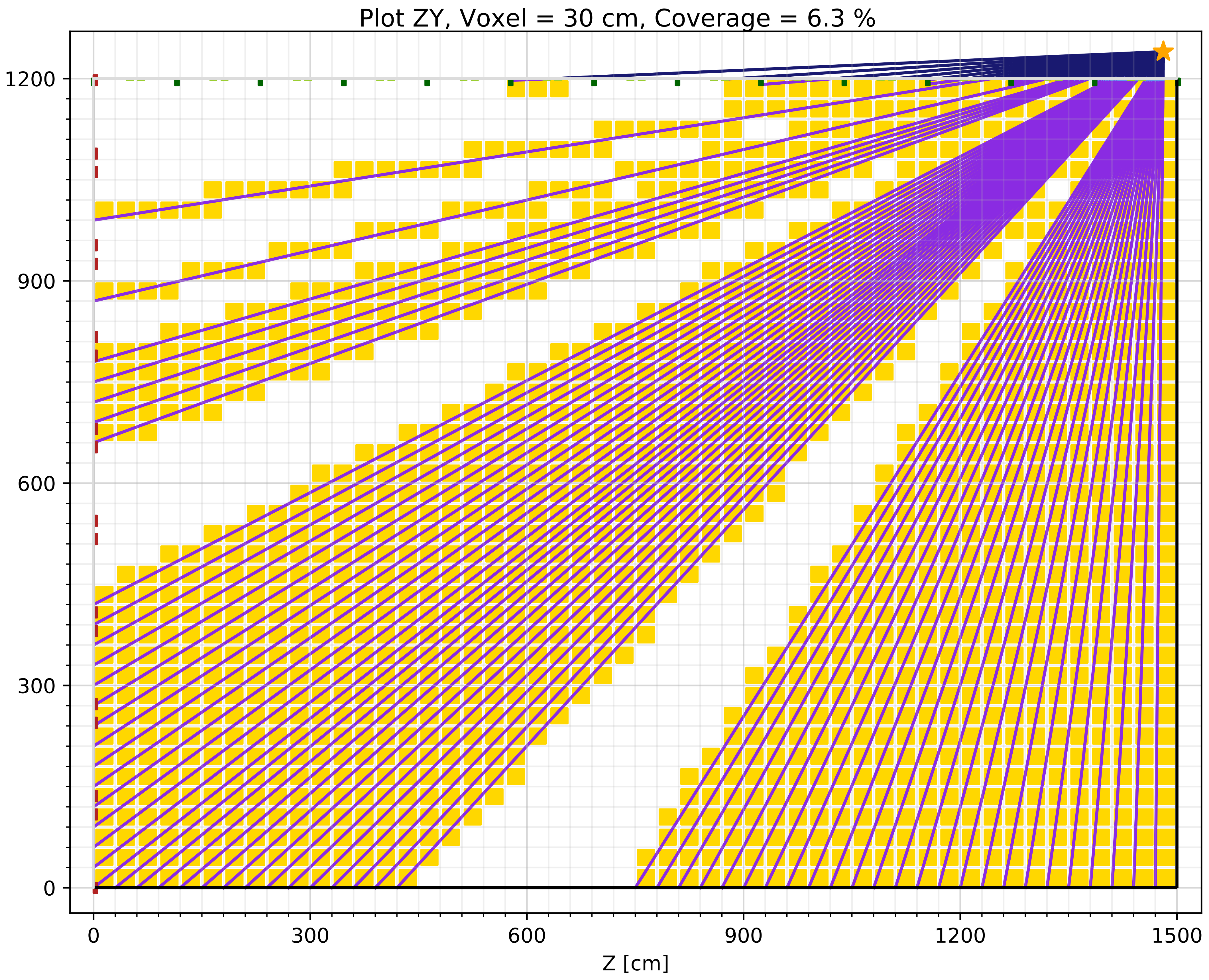
Include profiles	Vox = 30 cm	Vox = 10 cm
APA	56.4%	27.1%
no APA	52.1%	29.0%

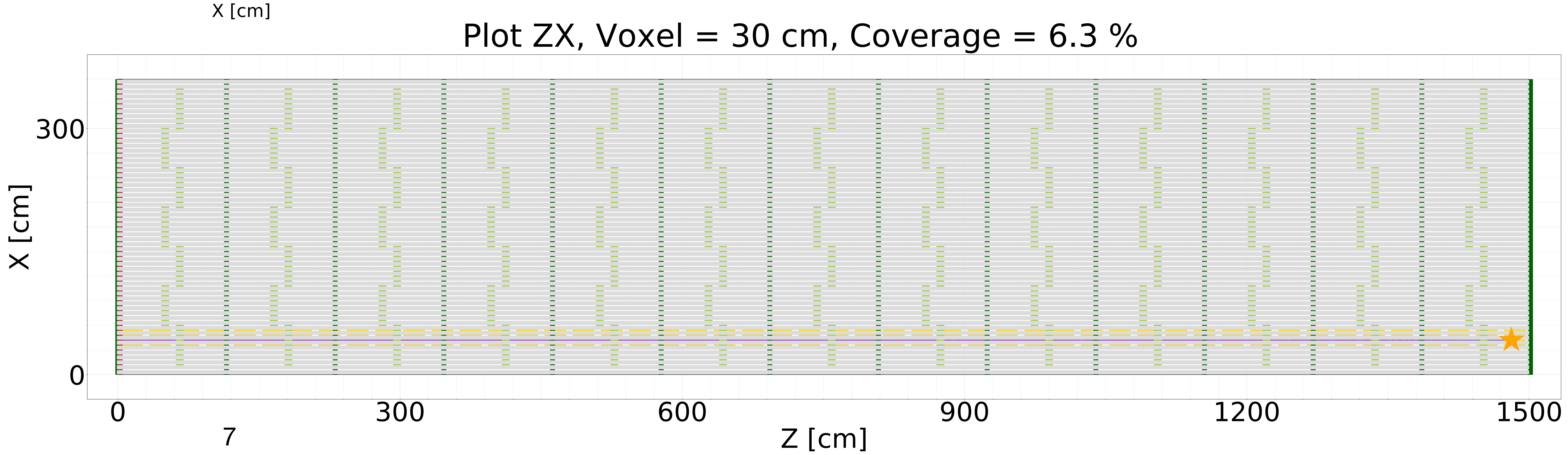


Extending to a 3D geometry

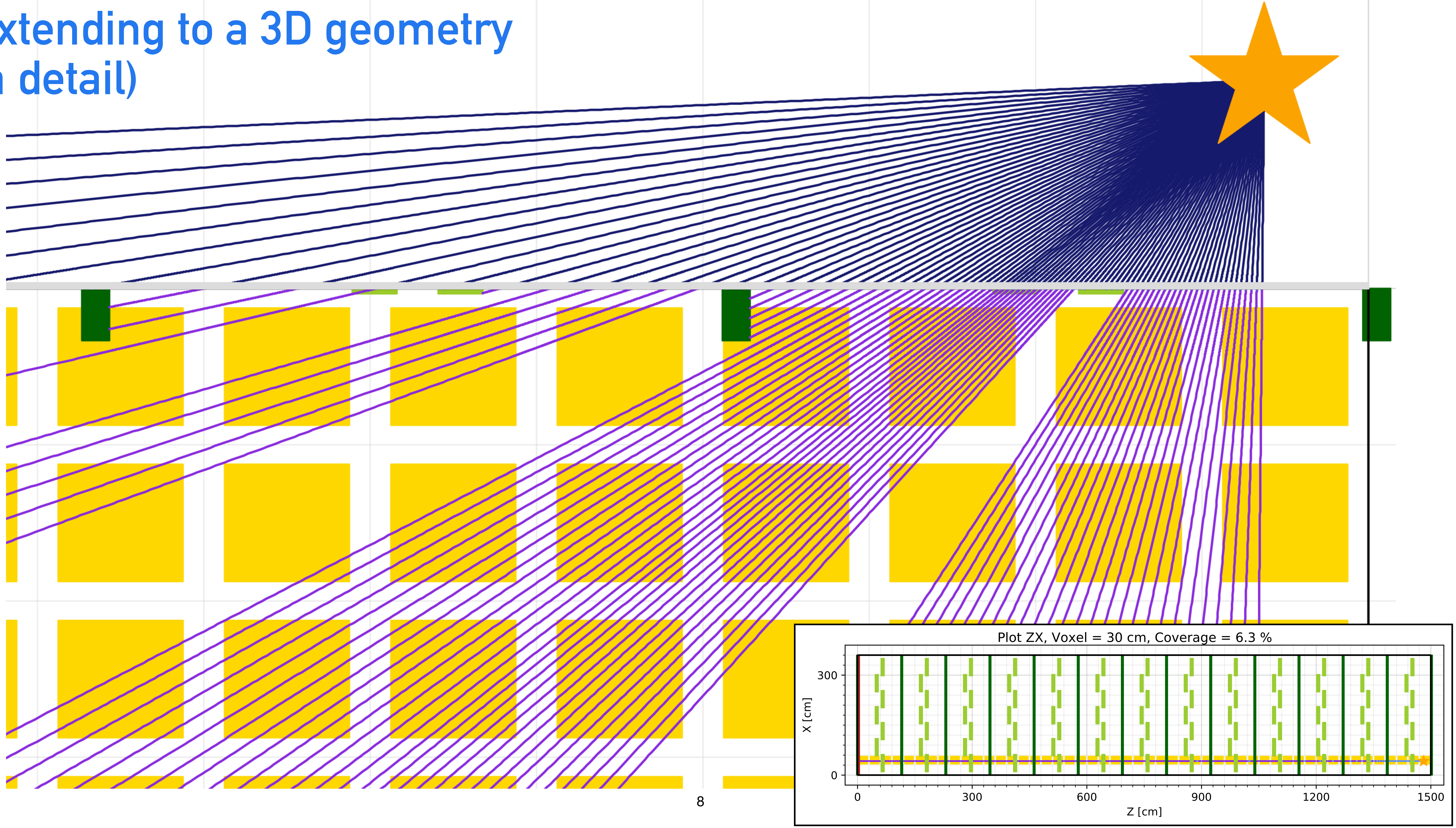
- Objects can be separately included in each run (two points, offset, gap, 6 +1 +1 parameters)
- Detector dimension can be easily redefined
- One laser ray is a set of points with three coordinates each. The first point is the laser fire-point. All the others are obtained by summing an increment
- The increment direction is given by the three normalised coordinates and rounded to the voxel size. Obstacles check is done here
  - Lines are counted as
    - Out of the detector (dark blue)
    - Entering the detector (not visible here)
    - Inside the detector (violet)
- To turn on the single voxels, points are normalised to the voxel dimension. Duplicate points are removed. The length of such array corresponds to the number of voxels crossed by a track





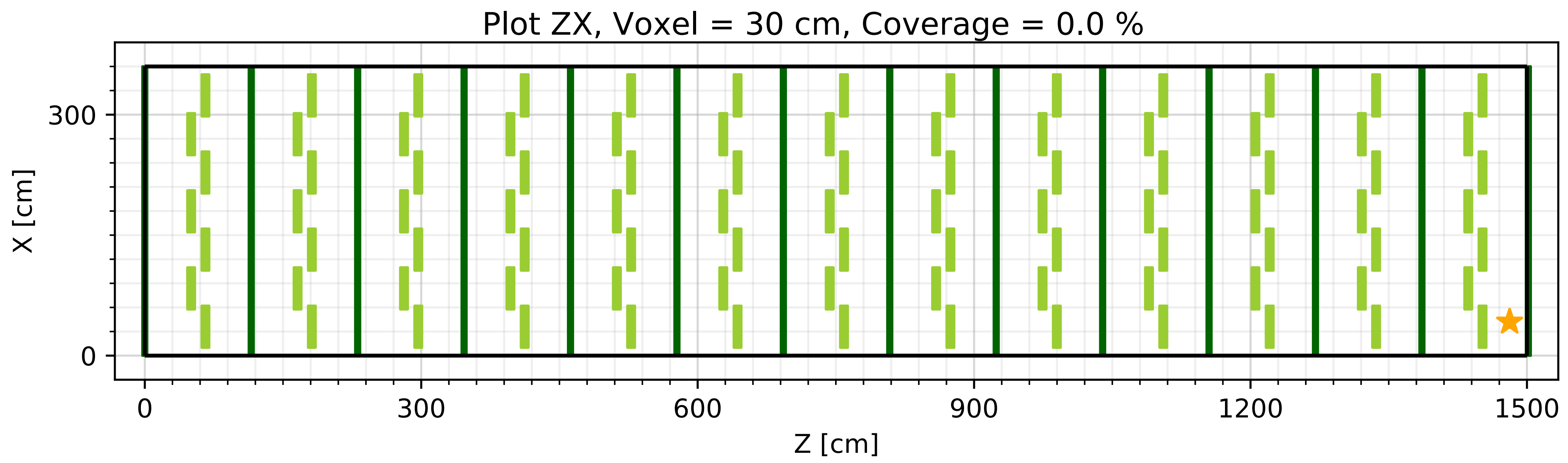


Extending to a 3D geometry (a detail)



Computing a full coverage calculation

- Ray-set:
  - Destination point (x,y,z)
  - Address all voxels
  - Half-voxel step (= 27 tracks per voxel)
  - Highest coverage reached
- Line3D:
  - 9 mm step safe region, 0.9 mm close to obs
- Considerable amount of computing resources
  - ➡ No graphic output
- 10 cm voxel simulation is extremely challenging



Voxel_30cm, **ifAPA_True**

1.
No obstacles:
[x] Top FC profiles
[-] End-wall FC profiles
[-] End-wall supports
[-] Top I-beams
[-] Top resistor plates

Defining laser rays…
Computing tracks…
Number of total generated tracks: 179883
Number of rays not crossing the detector: 0
Number of rays blocked by obstacles: 145907
Number of rays crossing the active region: 33976

Covered voxels: 14373 of 24000; Coverage = **59.9%**

2.
Including obstacles:
[x] Top FC profiles
[-] End-wall FC profiles
[-] End-wall supports
[x] Top I-beams
[x] Top resistor plates

Defining laser rays…
Computing tracks…
Number of total generated tracks: 179883
Number of rays not crossing the detector: 0
Number of rays blocked by obstacles: 153811
Number of rays crossing the active region: 26072

Covered voxels: 12140 of 24000; Coverage = **50.6%**

Voxel_30cm, **ifAPA_False**

3.
No obstacles:
[x] Top FC profiles
[-] End-wall FC profiles
[-] End-wall supports
[-] Top I-beams
[-] Top resistor plates

Defining laser rays…
Computing tracks…
Number of total generated tracks: 165018
Number of rays not crossing the detector: 0
Number of rays blocked by obstacles: 139550
Number of rays crossing the active region: 25468

Covered voxels: 13100 of 24000; Coverage = **54.6%**

4.
Including obstacles:
[x] Top FC profiles
[-] End-wall FC profiles
[-] End-wall supports
[x] Top I-beams
[x] Top resistor plates

Defining laser rays…
Computing tracks…
Number of total generated tracks: 165018
Number of rays not crossing the detector: 0
Number of rays blocked by obstacles: 145566
Number of rays crossing the active region: 19452

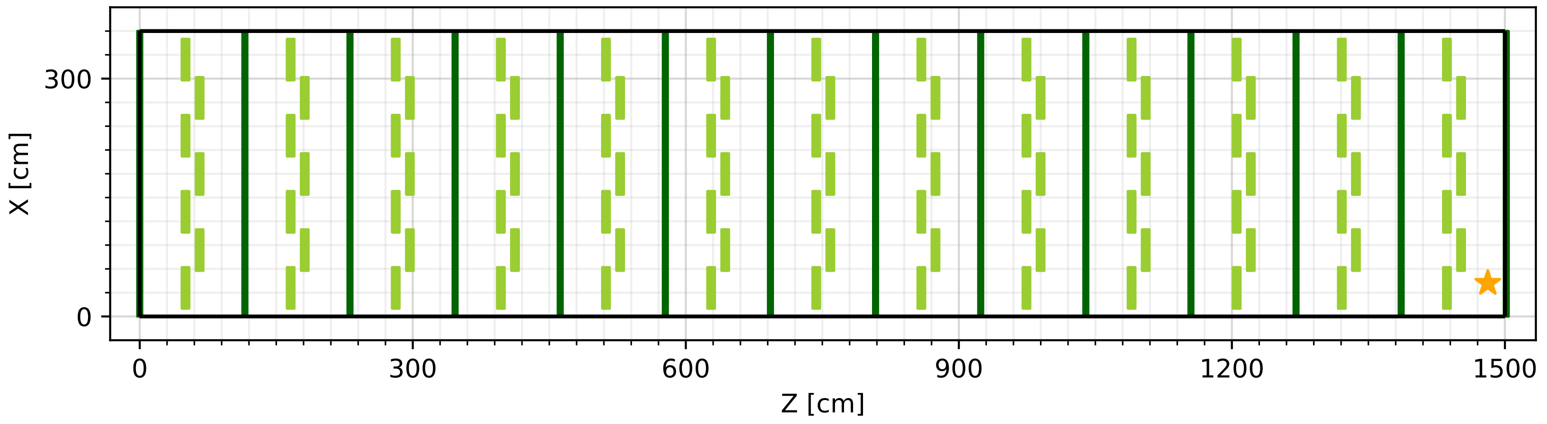
Covered voxels: 11007 of 24000; Coverage = **45.9%**

Computing a full coverage calculation

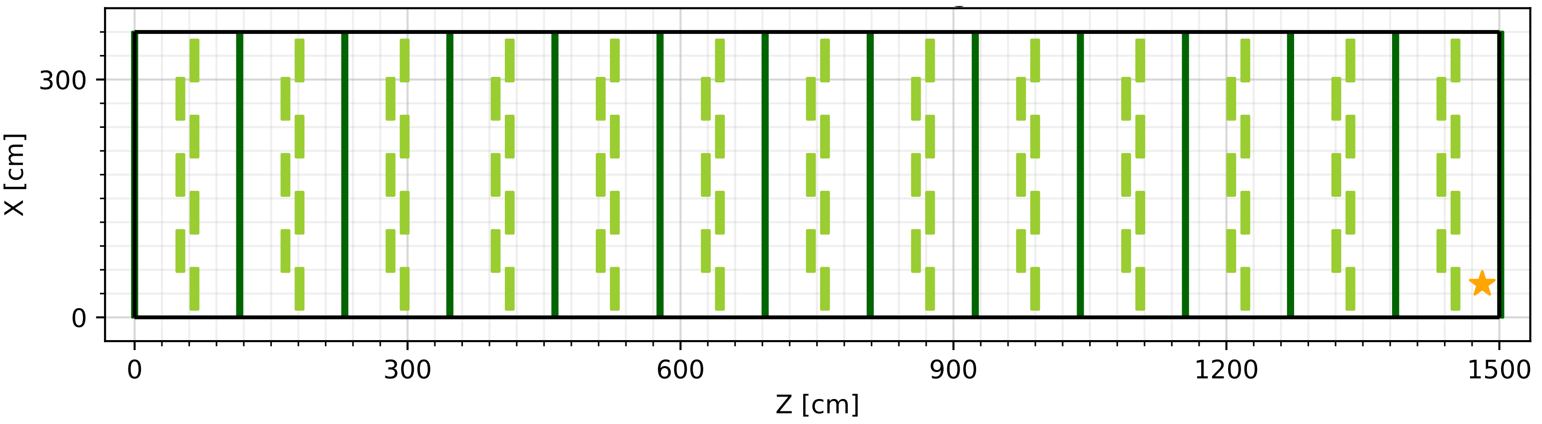
Five laser fire-point heights

Three main configurations:

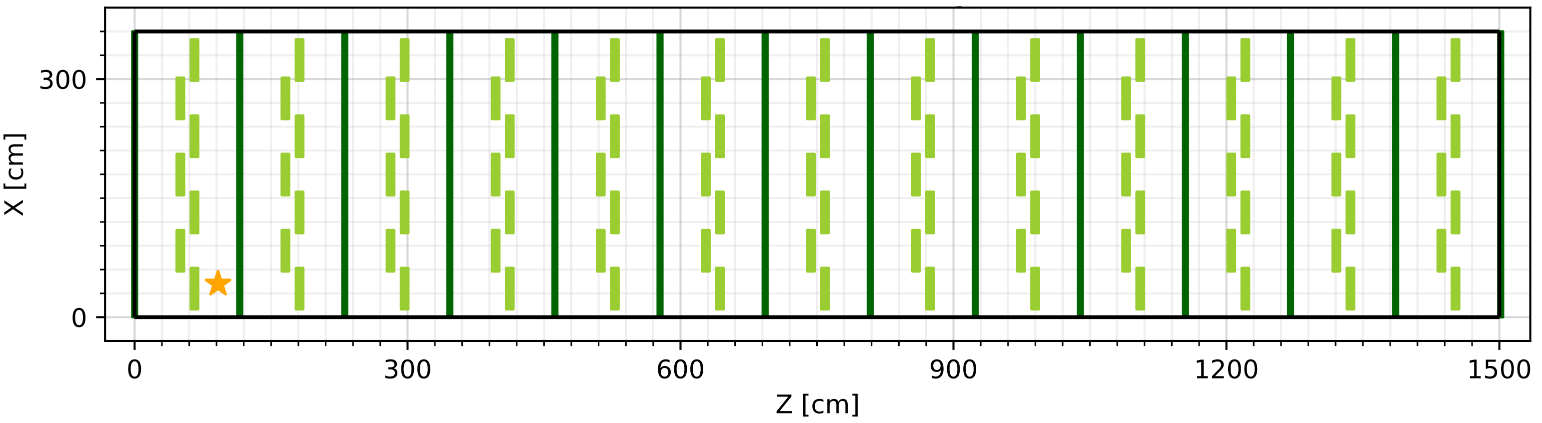
First obstacle = ‘far’ resistor plate



First obstacle = ‘close’ resistor plate



First obstacle = I-beam



Vox = 30 cm		
First obstacle = Resistor plate (close)		
h = 40 cm	APA	noAPA
noObs	**59.9%**	**54.6%**
Obs	**50.6%**	**45.9%**
h = 30 cm	APA	noAPA
noObs	**55.3%**	**52.2%**
Obs	**45.2%**	**41.7%**
h = 20 cm	APA	noAPA
noObs	**46.9%**	**45.3%**
Obs	**37.4%**	**35.7%**
h = 10 cm	APA	noAPA
noObs	**37.6%**	**35.8%**
Obs	**31.6%**	**30.4%**
h = -25 cm	APA	noAPA
noObs	**100.0%**	**99.4%**
Obs	**100.0%**	**99.4%**

Vox = 30 cm		
First obstacle = Resistor plate (far)		
h = 40 cm	APA	noAPA
noObs	**59.9%**	**54.6%**
Obs	**50.5%**	**45.8%**
h = 30 cm	APA	noAPA
noObs	**55.3%**	**52.1%**
Obs	**46.8%**	**43.7%**
h = 20 cm	APA	noAPA
noObs	**46.9%**	**45.3%**
Obs	**40.6%**	**38.9%**
h = 10 cm	APA	noAPA
noObs	**37.6%**	**35.8%**
Obs	**32.8%**	**31.6%**
h = -25 cm	APA	noAPA
noObs	**100.0%**	**99.4%**
Obs	**100.0%**	**99.4%**

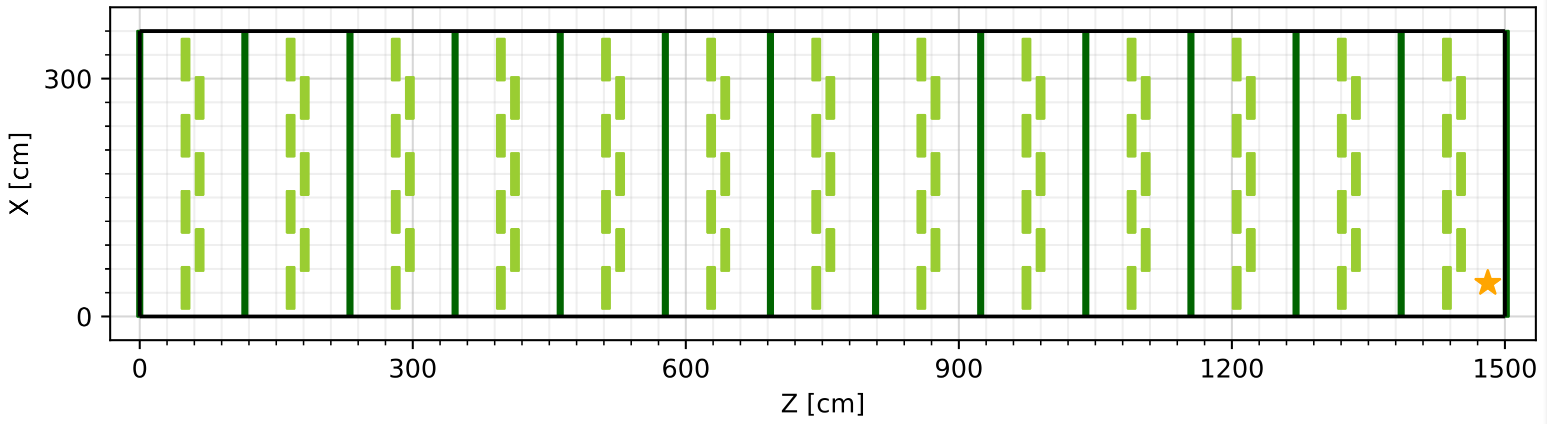
Vox = 30 cm		
First obstacle = I-beam		
h = 40 cm	APA	noAPA
noObs	**59.9%**	**54.5%**
Obs	**51.9%**	**47.1%**
h = 30 cm	APA	noAPA
noObs	**55.3%**	**52.2%**
Obs	**45.8%**	**42.4%**
h = 20 cm	APA	noAPA
noObs	**46.9%**	**45.3%**
Obs	**34.3%**	**32.7%**
h = 10 cm	APA	noAPA
noObs	**37.6%**	**35.8%**
Obs	**25.7%**	**24.5%**
h = -25 cm	APA	noAPA
noObs	**100.0%**	**99.4%**
Obs	**100.0%**	**99.4%**

Computing a full coverage calculation

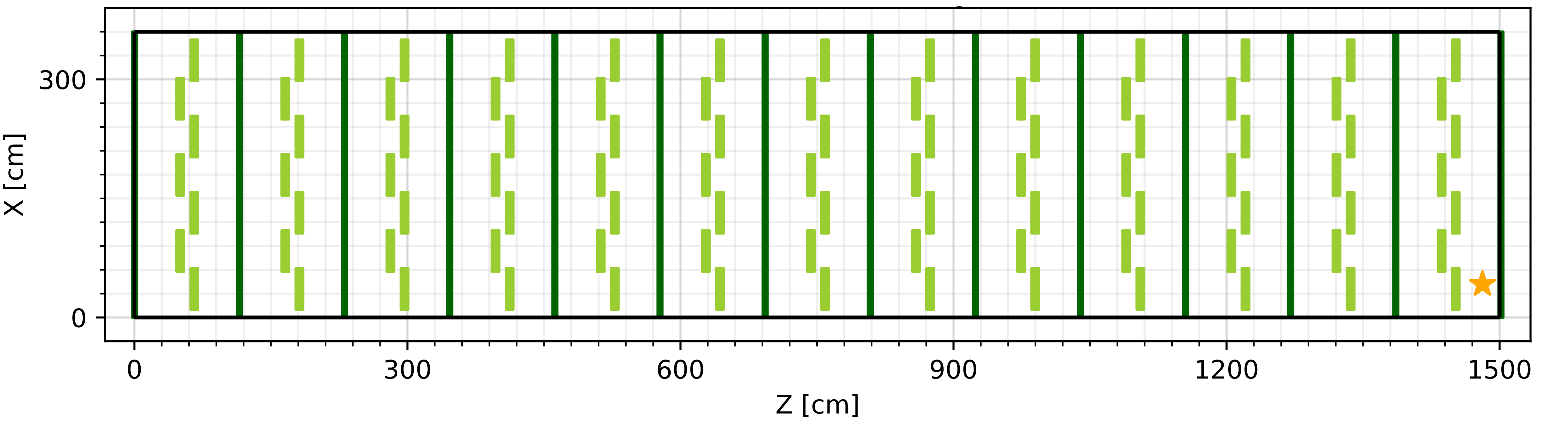
Five laser fire-point heights

Three main configurations:

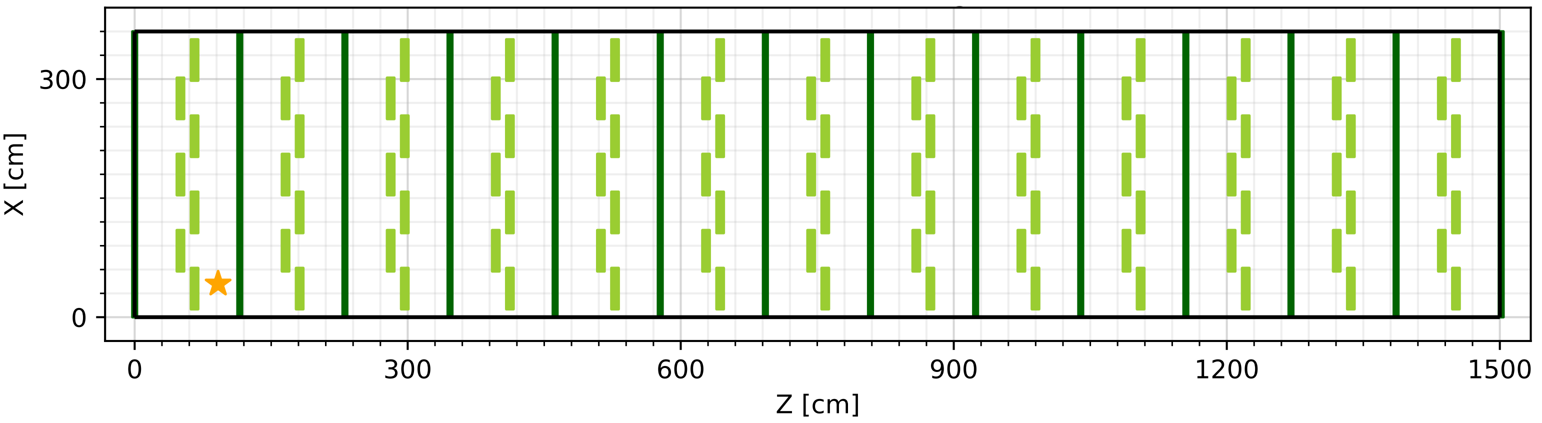
First obstacle = 'far' resistor plate (fRP)

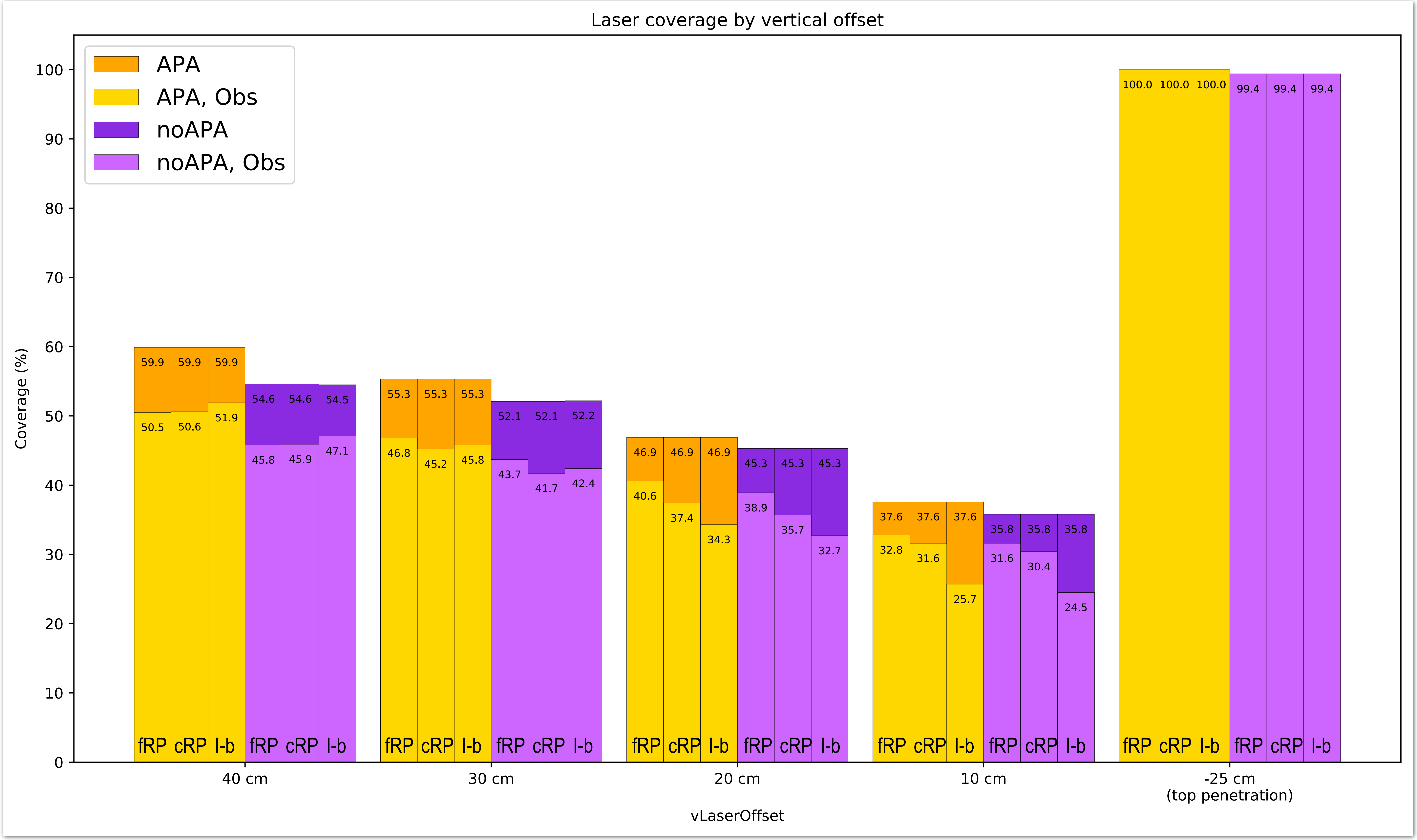


First obstacle = 'close' resistor plate (cRP)



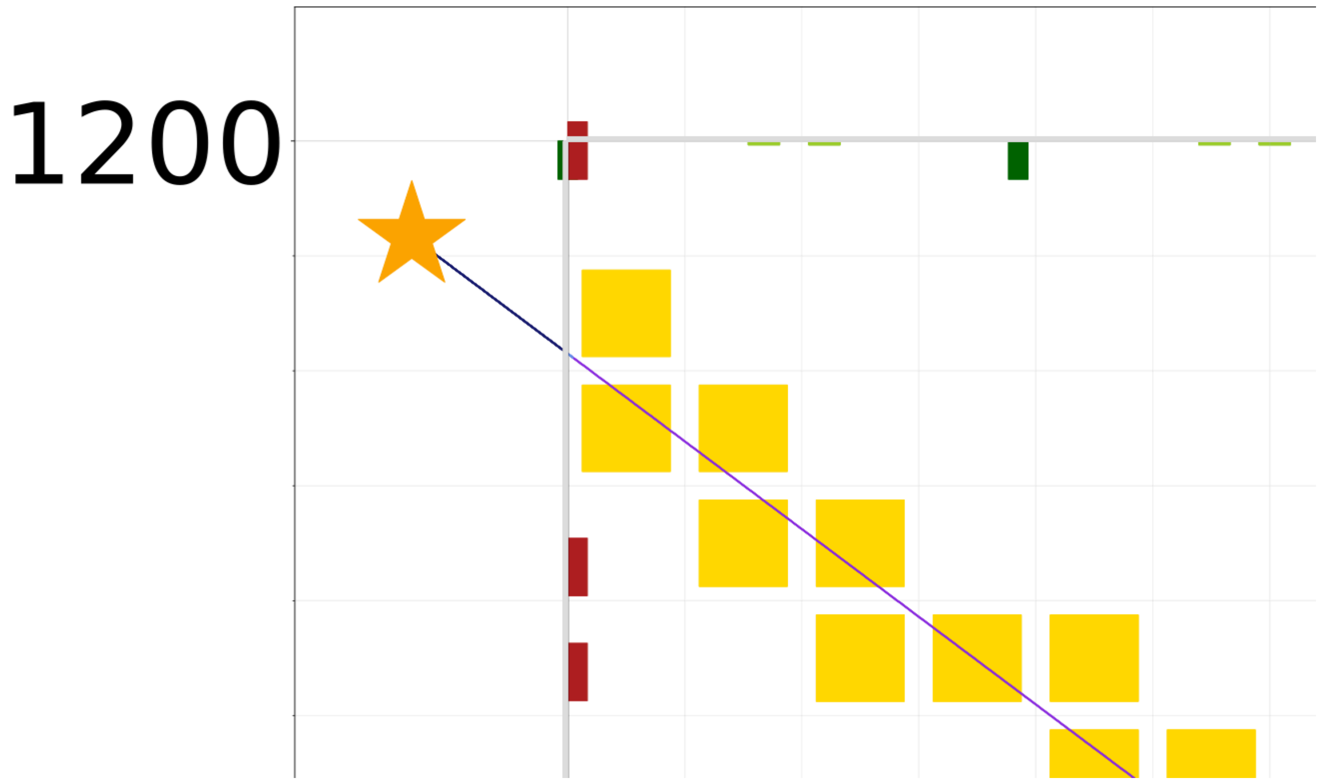
First obstacle = I-beam (I-b)

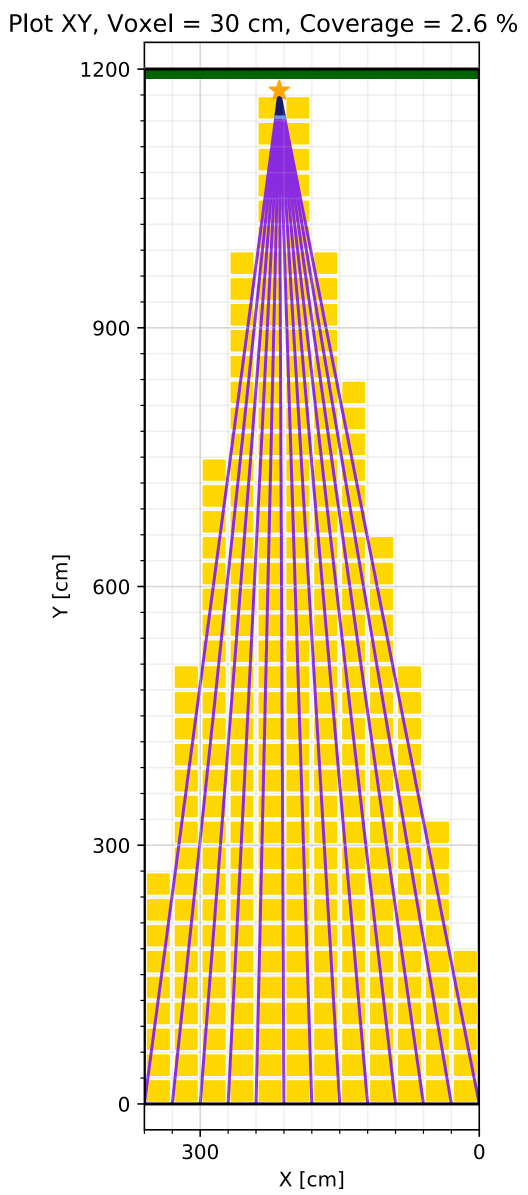


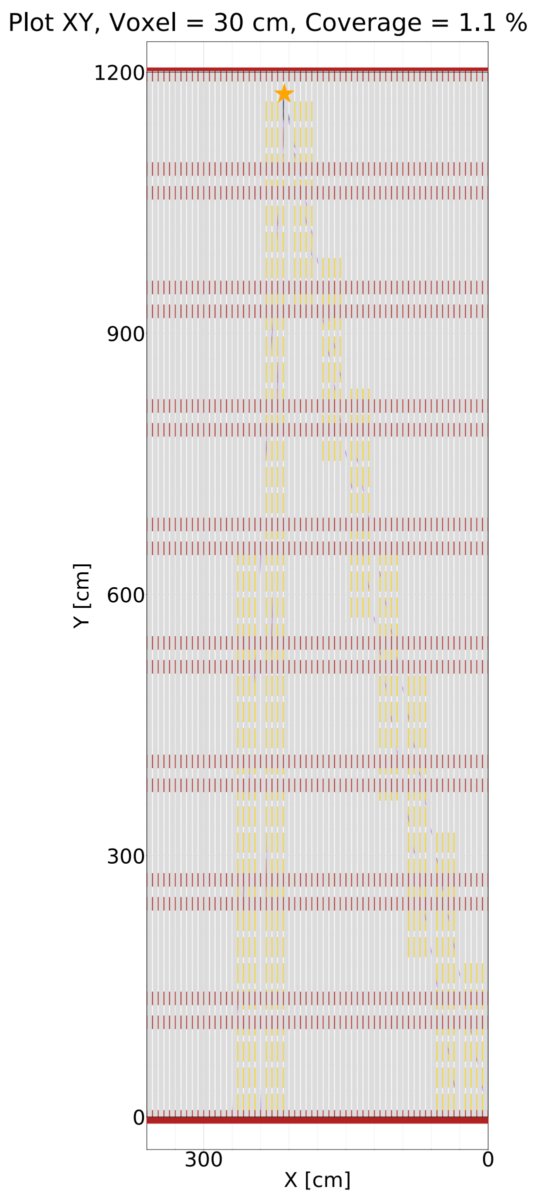


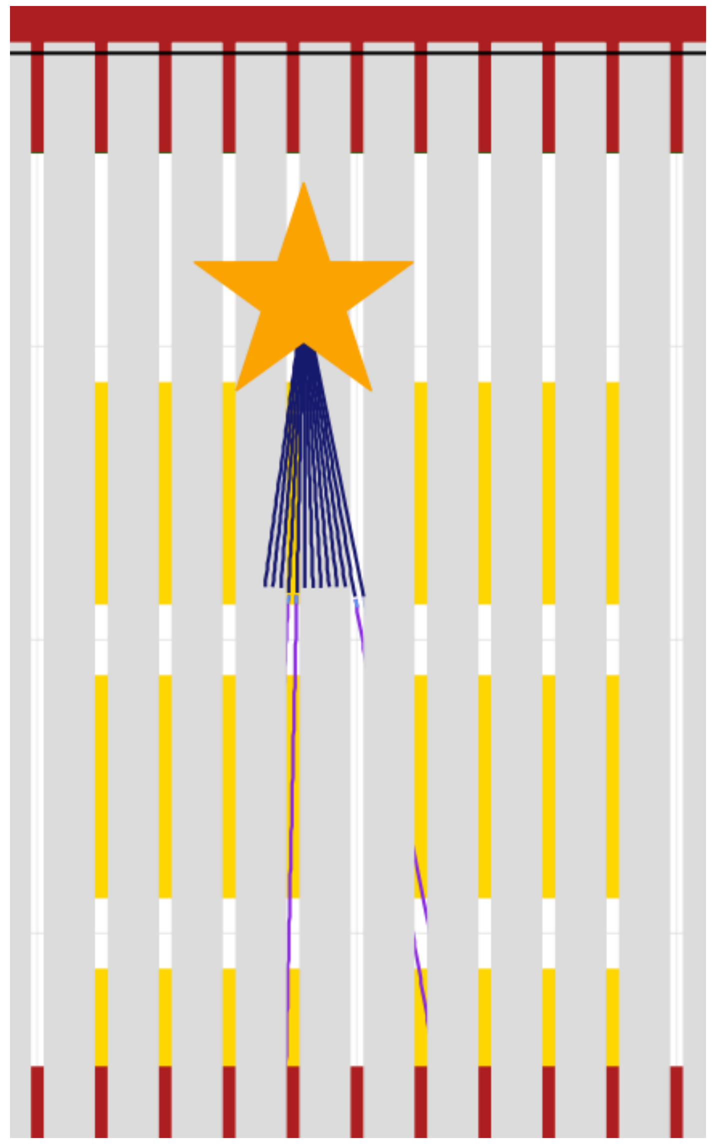
Future plans

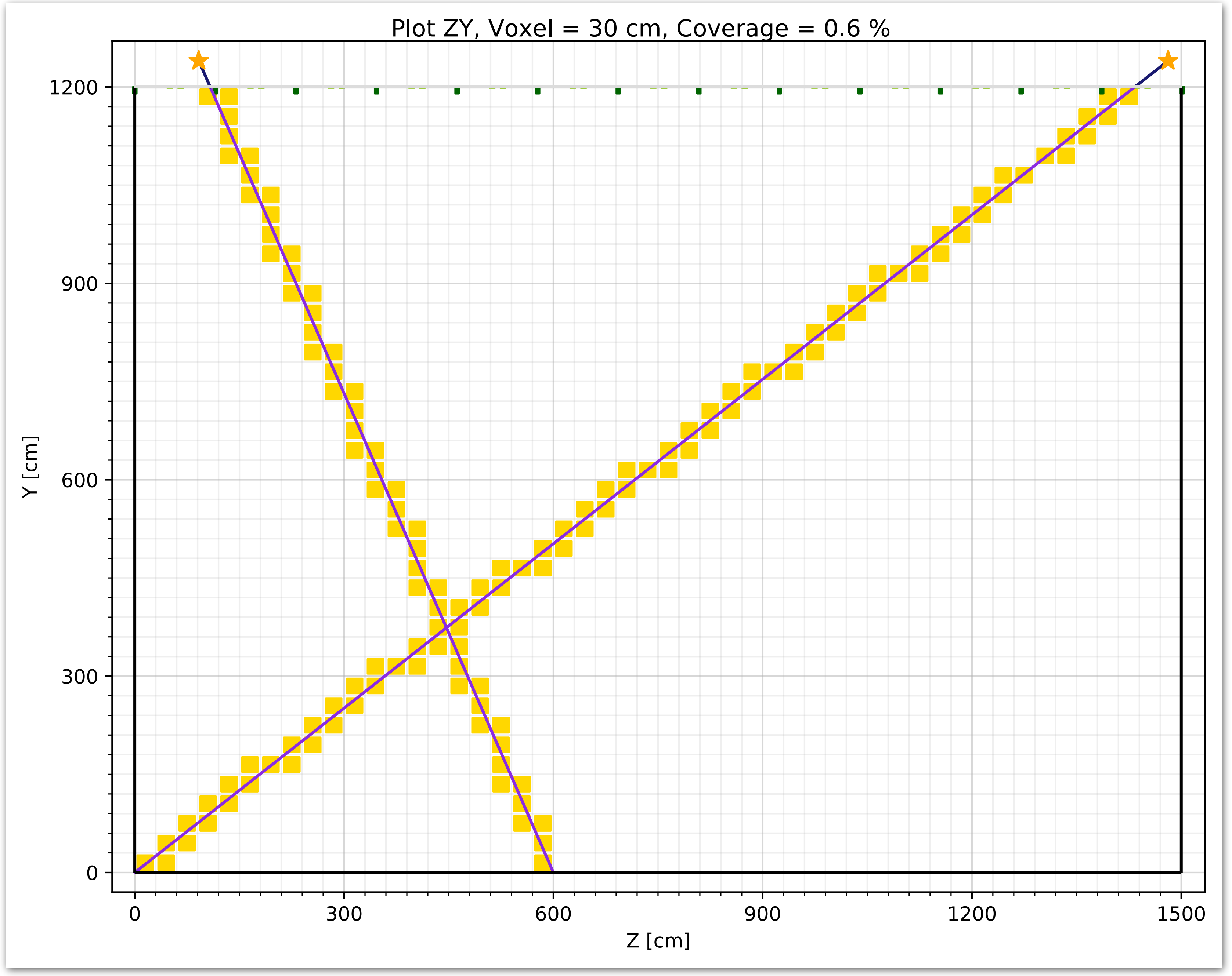
- Complete end-wall calculation
- Provide a coverage map for each sector (Obs-noAPA only)
- Provide a 10 cm voxel calculation (Obs-noAPA only)
- Develop crossing tracks calculation

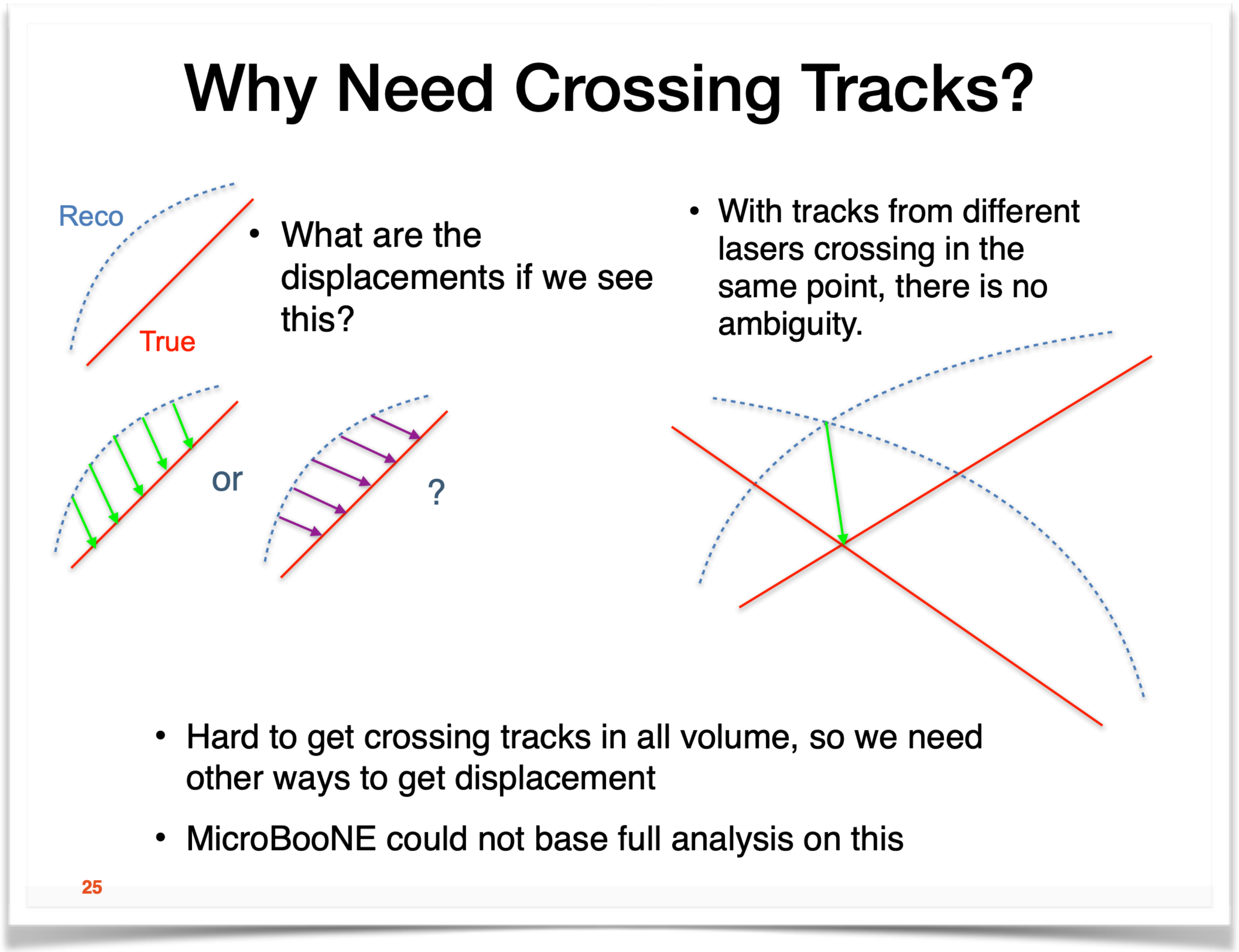


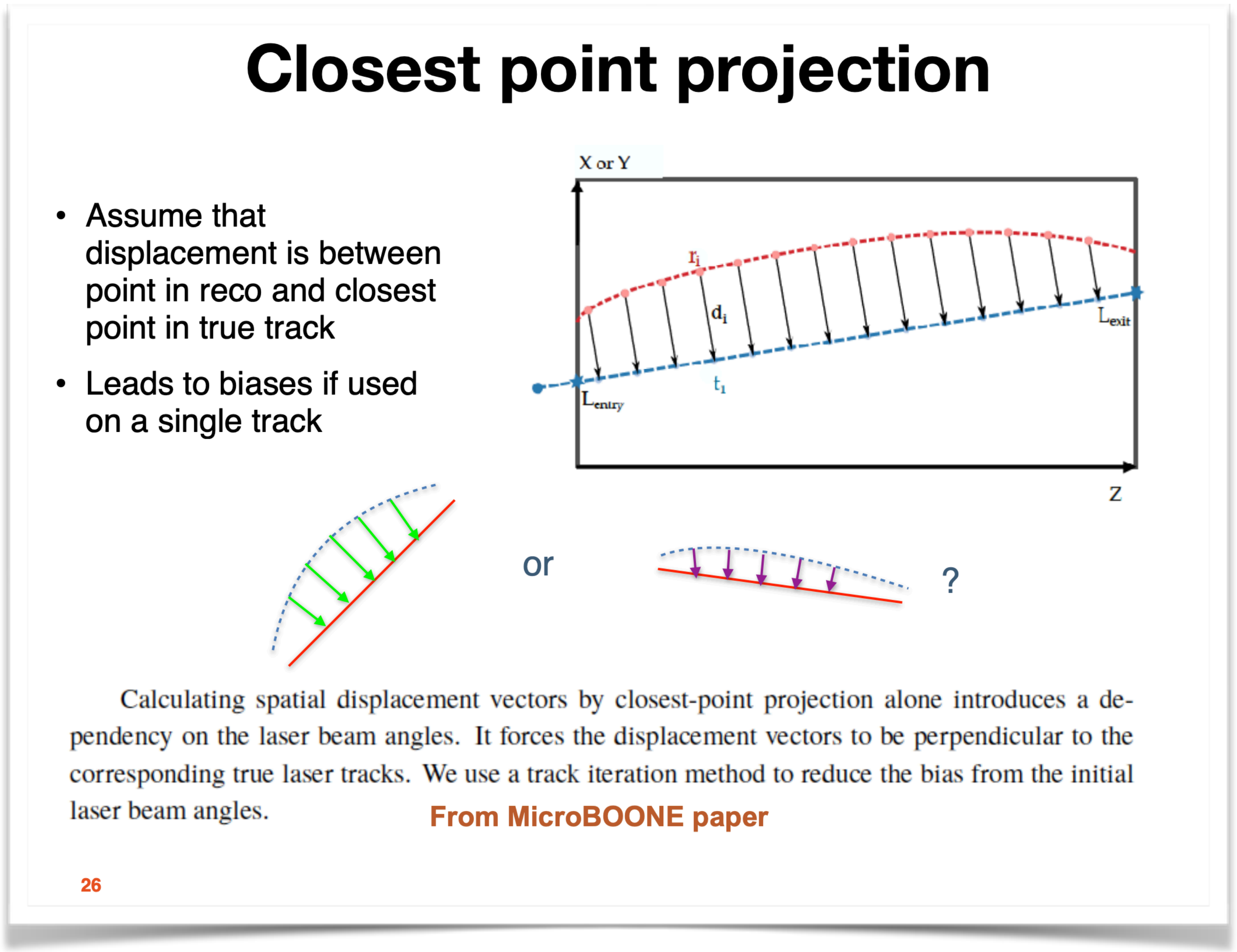












[S. Gollapinni, CALCI meeting 2020]